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ABSTRACT

A "world model" is constructed where precedent-searching is one of the primary driving mechanisms. The simulation assumes that nations in the system are utility maximizers but that they have relatively primitive decision mechanisms and that they are strongly influenced by their previous short-term successful behavior and the short-term success of other states in the system. This model of foreign policy decision-making has been heavily influenced by recent artificial intelligence studies and simulations. States in the simulation follow one of three distinct strategies to maximize growth: imperialism, militarism, or trade and, in each mode, a state can increase or decrease its level of behavior, or it can switch modes. The objective of simulation is to get away from the purely mechanistic difference equation formulations of world models while avoiding overly rational and optimizing models. Precedent-based decision-making is plausible for a goal-seeking system which, because of bureaucratic constraints, is capable of only fairly simple behaviors. The simulation uses a system vaguely characteristic of the 19th century world system with 5 large, 5 medium, and 10 small nations. The resulting behavior is generally plausible with bounded and fairly diverse activity depending on the random experimentation involved. Because of the weak bounded rationality, the system does not lock on to a single pattern of behavior based on initial conditions and so, for example, siutations exist where medium powers eventually become stronger than the initial major powers. The most common pattern is one of a combination of trade links and imperialism, with about half the minor powers being colonized and some exchange of colonies occurring through conflict. An appendix, "Key Elements of PWorld Program", and a bibliography are included. (Author/KWL)

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PWORLD: A Precedent-Based Global Simulation

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ABSTRACT

A "world model" is constructed where precedent-searching is one of the primary driving mechanisms. The simulation assumes that nations in the system are utility maximizers but that they have relatively primitive decision mechanisms and that they are strongly influenced by their previous short-term successful behavior and the short-term success of other states in the system. This model of foreign policy decision-making has been heavily influenced by recent artificial intelligence studies and simulations.

States in the simulation are assumed to be able to follow one of three distinct strategies to maximize growth: imperialism, militarism or trade. In each of these modes, a state can either increase or decrease its level of behavior, or it can switch modes. Decisions to switch are based on evaluating the success of the policy in increasing simulated GNP in comparison to earlier projections of how much GNP would increase. If a policy is clearly not working, a nation implements the reverse of that policy; if the policy is not producing major improvements, it randomly experiments or looks at the success of other nations in the system and follows whatever has worked for them; if a policy is clearly successful, it is continued.

The objective of the simulation is to get away from the purely mechanistic difference equation formulations of world models which have characterized most of the work in this field, while avoiding overly rational and optimizing models which have been characteristic of some other work. Precedent-based decision-making is plausible for a system was is goal-seeking, sentient with respect to its environment but still, due to bureaucratic constraints, capable of only fairly simple behaviors. It was incorporates the fact that the international system goes through various regimes which dominate the type of behavior used by the major states in the system.

The simulation is run using a system vaguely characteristic of the 19th century world system, with five large, five medium and ten small nations. The resulting behavior is generally plausible, with bounded and fairly diverse activity depending on the random experimentation involved. Because of the weak bounded rationality, the system does not lock on to a single pattern of behavior based on initial conditions and so, for example, situations exist where medium powers eventually become stronger than the initial major powers. The most common pattern is one of a combination of trade links and imperialism, with about half the minor power being colonized and some exchange of colonies occurring through conflict.

1. Introduction

World models have proliferated since their initial development as human-machine models in the 1950's by Harold Guetzkow (see, e.g. Guetzkow and Valadez 1981) and their popularization in the 1970's as all-machine models through the efforts of the Club of Rome (see, e.g. Meadows, Richardson and Bruckmann 1982, Deutsch *et al* 1977), the International Institute for Applied Systems Analysis (see Hickman, 1983) and others. A recent survey (Siegmann 1985) lists 27 different major modeling efforts worldwide. For a survey of the current "state of the art" in global modeling, see Ward (1985) and Hughes (1955).

The dominant tendency in all-machine models has been to focus on systems of difference equations. This is convenient since these equations are easily simulated with a digital computer; it is consistent with the engineering ancestry of most of the all-machine simulations (as well as with the related Richardson modeling tradition in international relations); and it allows the systems to be fairly easily estimated using conventional statistical techniques. The difference equation approach to global modeling is certainly a good first approximation, and judging from the proliferation of such models, it has a fair amount of heuristic utility as well.

The disadvantage of the difference equation approach, however, is that it ignores most of the cognitive characteristics of human foreign policy decision making. *Ipso facto* it would appear that human beings are to some extent goal seeking, that they respond to observed activities in their environment in qualitative as well as quantitative ways, and that they have memory which can be utilized for learning. The difference equation approach is also somewhat unsatisfactory because the resulting models tend to exhibit either too much regularity -- producing a world which is unrealistically consistent and reflects only the extrapolation of existing trends -- or alternatively the models yield catastrophic behavior where the model blithely sidles up to the edge of an abyss without taking ameliorative action, and then just as blithely hops into the abyss.

The most common solution to the lack of cognition in these models is to use the so-called "rational choice" approach, which substitutes for deterministic mechanisms of the difference equation an expected utility optimizing mechanism borrowed from economics. Rational choice models in international relations have been popularized by Brito and Intriligator (1973, 1974, 1982, Intriligator and Brito, 1984). Bueno de Mesquita (1981) and the dynamic optimization work of Gillespie and Zinnes (1975, 1977, 1978). Unfortunately, these models have usually been applied only in the two-nation case -- in large part because of the complex specifications and mathematical manipulations required to use the models -- and as a consequence they have had little direct application in the

global modeling literature. An additional problem with the work -- particularly in the dynamic optimization models of Gillespie *et al* -- is that an excessive degree of rationality is called for, particularly when one considers that decisions being modeled are in the real world implemented by complex bureaucracies which tend to favor simple solutions to problems and do not appear to use a great deal of foresight.

1.1. Pattern Matching and Learning

As I have argued extensively elsewhere (Schrodt, 1984a,b; Schrodt, 1985a), an alternative to difference equation and rational optimization in modeling international systems is to emphasize the key role of precedent-seeking in organizational decision-making. When precedent-seeking is combined with some simple performance criteria, it can also provide for simple learning-by-example by the system. With modern computer programming techniques, these characteristics of cognitive behavior can easily be incorporated into a global simulation.

A precedent-based approach starts from the obvious fact that decision-making individuals and organizations have an base of past experiences. When trying to predict the consequences of a particular option, that data base is searched for past experiences which match the existing situation as closely as possible according to some pattern-matching criterion. Those past experiences are then used to determine the current action: one looks at the previous cases to predict in a heuristic fashion what the likely consequences of various possible responses to an event will be. The response which produces the best predicted outcome is the one implemented.

In general, the pattern matching approach seeks to match events with past events which are in some sense similar. This approach as been variously termed "analogy" or "precedent". The use of analogy with historical sequences in the context of foreign policy analysis is discussed by Mefford (1984), formalizing the notions of "focused comparison" developed by George (1979). Precedent-based approaches are used in Mefford (1984), Anderson (1981), Bonham and Shapiro(1976), Tanaka (1984), Alker and Christensen (1972) and Alker and Greenberg(1973). Other information-intensive approaches which utilize heuristics in addition to precedent are found in Bennett (1984), Isard and Lewis (1984), Majeski (1985) and Sylvan and Majeski (1983), and more generally the "computational modeling" or "artificial intelligence" approach to modeling international events. The potential importance of this in political reasoning is also discussed in Simon (1985).

The argument for the analogical approach can be made from several standpoints. As Mefford (1984) illustrates with respect to the Soviet invasion of Czechoslovakia and other examples, the incidence of analogy is very high in published justifications for policy

actions, and in reported policy discussions. While analogy is rarely used as an empirical technique, it clearly is a common mode of reasoning in policy formulation -- for example the analogical terms "Munich", "Vietnam", "Pearl Harbor" and so forth are some of the most powerful constructs in the foreign policy lexicon of the United States. The use of these analogies may appear in hindsight to be inappropriate or inconsistent but they are used

Studies of individual decision-making and artificial intelligence research have also emphasized the role of analogy. Herbert Simon (1979, Newell and Simon 1972) is one of the most visible proponents of this view; Carbonell (1983) and Winston (1979) also discuss the approach in detail. One also observes that in the teaching of international relations and foreign policy, virtually all instructors spend a large amount of time building an historical background upon which to analyze events by use of precedent. Even a behavioralist IR text such as Russett and Starr (1984) contains far more history than, for example, Samuelson's Economics. The introductory chapters of Morgenthau's Politics Among Nations contain on average four historical examples per page

The use of pattern-matching in the policy model is consistent with the fact that the human brain is considerably more efficient at the storage and recall of information than at the logical manipulation of information. As Simon (1985) has pointed out, extensive experimentation in the cognitive sciences has shown that the human brain is extraordinarily good at recall -- a process which seems to operate in parallel on billions of items of information -- but is constrained in logical processing to a slow, serial process operating on a limited (around six items) short-term memory cache. For example, most evidence indicates that chess experts use large amounts of pattern recognition as shortcuts to problem solving, and their performance slows considerably when they actually have to problem-solve. Mathematicians work the same way, and most research in expert systems confirms the requirement for a large base of 'experience' through which the system can find a solution.

In other words, thinking is often recall masquerading as reasoning. This emphasis on the empirically demonstrated limitation of the logical reasoning capabilities of the brain leads to the general approach of "bounded rationality" as a modeling technique, which is more cognitively complex than difference equations, makes fewer demands on assumptions about human reasoning than rational choice, and is mathematically and conceptually more complex than either

Just as humans tend to employ recall as a technique, an organization may depend largely on precedent and standard operating procedure when dealing with day-to-day problems, and a mature organization may develop sufficient experience that analytical problem solving is virtually eliminated until such time as an unprecedented crisis occurs

If this is in fact the typical pattern of organizational behavior, then any attempt at the construction of a political reasoning model solely out of logical principles will at best only partially approximate actual behavior. The question for *homo politicus* is not only "what do I want?" but also "what is attainable and how?" -- politics as the art of the possible. The single strongest argument for showing that something is attainable is to show that it is has been attained in the past, and to use the method by which it was attained by as a guide. That in turn means that behavior will be driven by historical information at least as much as by logic or rules.

As an organization gains experience -- that is, accumulates historical information -- its behavior might be expected to change without any change in the policy, theory or preferences. In a word, organizations can **learn**. For example, the USA committed large numbers of Marines to Lebanon in 1957 and 1982 with the objective of stabilizing the country, but the unpleasant experiences suffered by the Marines in 1983 makes future deployments less likely. This change is due to a modification of the experience of the organization rather than a modification of objective. In this fashion the model provides a mechanism whereby changing the ***information base*** or ***history*** of the decision-maker rather than changing the **rules** of decision-making could alter behavior. This is in line with Simon's (1982:63) approach of modeling cognitive behavior as a set of simple rules operating in a complex environment, rather than complex rules operating in a simple environment.

Ironically, as Simon (1985) cogently pointed out to the political science discipline, the research in the cognitive sciences has been largely ignored by the decision-oriented social sciences, despite what would seem to be rather obvious connections between the two. Milton Friedman's infamous (1953) argument notwithstanding, it takes an extraordinary leap of blind faith -- yea, a demonstration of willful ignorance in the face of falsifying evidence usually confined to the study of economics -- to base dynamic models on mechanisms which virtually all of our empirical evidence indicates could not possibly be occurring. Yet the dominant mechanisms in most dynamic work are either blind, memory-free difference equations or analytically complex dynamic optimization routines. Much simpler approaches which utilize characteristics such as lagged feedback, learning, pattern recognition which are clearly part of the cognitive repertoire of every normal member of the human species have not had a major impact. The model proposed in this paper will demonstrate in a simple fashion how some of these things might be done.

2. The Model

The model discussed in this paper is a simple implementation -- a test-bed in a sense -- of a world model which would incorporate some simple cognitive components. The model itself is relatively small -- about 800 lines of Pascal code -- and does not have the sectoral or actor complexity of a SARUM or GLOBUS. However, the actors in the model are more cognitively complex than those in many existing models. In particular, the actors

- Choose among a discrete set of behaviors (policies) which differ qualitatively and focus only a single mode of behavior at a time
- Compare their current performance with earlier expectations about that performance, and if the policy is causing a deterioration in performance, it is changed
- "Observe" the success and failure of policies pursued by other actors in the system and use successful policies as a model for their own behavior

As such, the model incorporates in at least a primitive fashion the notions of bounded optimization and feedback, precedent-seeking and learning discussed above. In a very distant way, the model is related to the model of Zinnes, Van Houwelling and Van Atta (1969), which incorporated qualitative behavior shifts in a balance of power framework and used a complex recursive forecasting capability to decide optimal policies. The Zinnes, Van Houwelling and Van Atta model did not use precedent-seeking, was in a strictly balance of power framework without an economic or imperialist component and also -- to my knowledge -- was never successfully implemented. The use of comparison with other nations is also found in Bremer's (1977) SIPER model, itself based on Guetzkow's earlier INS work; SIPER is also interesting in that the decision component makes heavy use of a rule base. SIPER appears to be more heavily driven by its difference equations that this model however, and employs "smarter" and faster decision-making algorithms.

The underlying assumption in this model is that of bounded rationality, a world which is "muddled through" by organizations which try various discrete policies and change those policies very slowly. As noted earlier, this is quite consistent with most studies of bureaucratic decision-making and is, in a highly simplified fashion, in the organizational behavior tradition of Simon. The "learning" involved in this model is doubtlessly too simple, as it does not use more advanced machine learning techniques (see, e.g. Schrodt 1986a, 1986b) and does not incorporate a history beyond the start of the simulation, so that information about the utility of various policies is learned only slowly and through empirical experimentation. Precedent searching is done only over the immediate past

rather than the distant past. Nonetheless, this is not totally unlike the real world, particularly in a situation where the structure of the system has undergone major change and the actors are not fully familiar with how the new system will operate.

The model proposed here seeks to model the development of the world system in the pre-nuclear age. Vaguely, the period under consideration would be about 1700-1900, though since this work is purely exploratory no attempt has been made to empirically estimate the key characteristics of the system.

2.1. National Characteristics

The model uses a simple three-sector model of the economy:

Milex	Military expenditures
Trade	Foreign trade and profits from colonies
GDP	everything other than the above

The national performance is measured by a single variable called GNP which is defined as:

GNP = GDP - Milex - Trade

GDP is assumed to have linear growth (i.e. *ceteris paribus* is exponential) and provides the primary mechanism for growth which funds other activities.

$$GDP(t+1) = a * GDP(t)$$

Trade can also contribute to the growth in GNP, military adventures subtract from it.

In the model, Milex is always adjusted as a percentage of GNP, rather than in fixed amounts. Thus growth in either GDP or trade can increase the amount of military power available. When comparisons of military power are made, they are done in terms of absolutes.

2.2. Modes of Behavior

The model postulates seven different modes of behavior, which roughly correspond to the types of policies which a nation could undertake. The policies and their abbreviations are:

Neutral	Stay the course, make no change in existing policy	NEU
Economic:		
Liberal	Increase amount of trade	LIB
Autarkic	Decrease amount of trade	AUT

Military		
Bellicist	Start a war or increase military expenditures	BEL
Pacifist	Reduce military expenditures	PAC
Imperialist		
Imperialist	Acquire a colony if possible	IMP
Decolonize	Get rid of a colony	DEC

The details of the effects of these policies are given below

Neutral

This has no effect all parameters (e g colonies Milex trading partners) remain fixed This is the most common policy and nations revert to it when policies fail to be successful

Liberal

In the Liberal mode the nation seeks to find another trading partner In the model "trade" involves a fairly major benefit and in a sense is taken to be a serious committment to trade (e g along the lines of policies undertaken by nations such as Switzerland and Japan) Trade is made with another nation in the liberal or neutral mode and is done in fixed "chunks" (e g 2%) Trade is established with the nation closest in GNP and it is possible to have more than one "chunk" of trade with a given nation A nation may trade to a maximum of **Max_Trade** chunks of GNP

The actual amount of trade between two nations in a given year is equal to the small of the chunks -- in other words, there are no trade imbalances (unlike the real world) The model assumes a comparative advantage to trade so the effect of trade on change GNP is some multiple **Trade_Mult** (e g 1 02) of the amount of trade

Autarkic

The autarkic model breaks off trading relations Trade with the poorest nation on the current trading list is dropped

Because of the no-risk benefit of trade, this may appear to be a strategy which is always disadvantageous This is not the case since a rapidly growing nation may have reached the maximum level of trade and still have links with poor nations which were established earlier These are advantageous to break off then new links can be established with wealthier nations

Bellicist

Bellicist nations do two things. First, they look for a nation to attack. The criterion is to choose the nation which has the largest number of colonies and which is smaller than oneself. As a simplification, wars last only a single year, though one can engage in the same war in multiple years. Consistent with observed human behavior in the absence of alliances, once a nation is engaged in a war it does not become involved in another in that year. This absence of alliance activity is, of course, a major simplification of the model and strongly differentiates it from realist-based models such as Leavitt (1971) and Zinnes, Van Atta and Van Houwelling (1969).

Wars can end either as draws or as victories. The outcome is based on a probability

$$\mathbf{Prob(Victory)} = \frac{\mathbf{(Max_Mil - Min_Mil)}}{\mathbf{(Max_Mil + Min_Mil)}}$$

where **Max_Mil** is the military expenditures (i.e. **GNP*Milex**) of the more powerful nation and **Min_Mil** is the military expenditures of the weaker nation. This probability is zero when the two nations are equal and goes to one when **Max_Mil** >> **Min_Mil**. If there is a victory, the stronger nation always wins, another a simplification.

Whether a war ends in a victory or a draw, it costs (i.e. decreases GNP) both nations involved as a proportion of their military expenditures. This proportion is

War_Cost * (Min_Mil / Max_Mil)

which is maximized when **Max_Mil = Min_Mil**. **War_Cost** is a proportionality constant which is set to 1.0 in the initial experiments.

A **Draw** results only in the decrease of GNP and the Mode of both nation is set to Neutral,on the logic that after a war both nations will be engaged in rebuilding for a time.

A **Victory** by the stronger nation involves a transfer of all of the colonies from the defeated nation to the victor, a decrease in the Milex of the defeated nation, and a transfer of **War_Spoils** percent of the defeated nations GNP to the victor. The mode of the defeated nation is changed to Neutral; the mode of the victor does not change.

If a bellicist nation cannot start a war, it increases the amount of GNP devoted to military expenditures by a fixed amount in order to raise the military expenditures to a point where an attack is possible. Obviously only a single nation (the weakest) will not be able to attack anyone, so this feature is unlikely to have much effect on the simulation.

If a bellicist nation is a colony, it revolts: it attacks the colonizer. Because colonies are substantially weaker than the colonizers they never win the revolt, but the War_Cost of

the attack costs the colonizer and reduces the wealth of the colony so that it is more likely to be let go War_Spoils are not distributed in revolts

Note that the bellicist policy in this simulation is fairly expensive (a characteristic which it shares with the real world) and will pay off only through the elimination of rivals, the acquisition of colonies, and attacking nations which are substantially weaker

Pacifist

The pacifist mode decreases Milex by a fixed amount which in turn will increase the amount of economic growth Milex cannot be decreased below a level **Min_Milex**

Imperialist

A nation in the imperialist mode seeks to acquire colonies To acquire a colony, the nation seeks out the weakest nation in the system, and the GNP of that nation must be below a certain percentage of the GNP of the imperialist (e g 25%) Imperialism succeeds if the imperialist has a victory in a war with the potential colony all of the effects of war discussed above hold for colony acquisition

The effects of acquiring a colony are the following

Colonizer	1 Increase Milex by fixed amount to account for cost of maintaining control of the colony
	2 Colonizer subsequently gets fixed % of GDP of colony
	3 GDP decreases by the cost of war for acquisition
Colony	1 Fixed % of GDP is lost to colonizer each year
	2 Intrinsic growth rate is increased
	3 GDP decreases by the cost of war for acquisition

Decolonize

In this mode, the nation gets rid of its weakest (lowest GNP) colony, and adjusts Milex accordingly While in general it is advantageous to hold onto colonies, getting rid of them has several advantages First, the decrease in Milex increases economic growth Second getting rid of colonies reduces the likelihood that one will be attacked by a bellicist nation, since the targets of bellicist nations are chosen on the basis of colony holdings Finally, getting rid of a colony eliminates the cost of dealing with revolts

2.3. Optimization Rule

Optimization in the simulation is essentially rule-based and involves first choosing the mode of behavior, then making some fairly simple choices in the implementation of that mode.

The key variable in deciding whether to change policies is to figure out whether the nation is doing as well in terms of GNP growth as it had projected. This is measured by a variable called **Performance**, which is the ratio of the current GNP to the GNP level projected two years before. The projections assume that everything in the system remains fixed: it just iterates the system forward two years with no policy changes or other activities.

If Performance is worse than a level **Bad_Policy** then the nation either reverses the policy it followed when the projection was made or, if that policy was Neutral (i.e. the policy itself wasn't doing anything, so by inference something elsewhere in the system must have changed), the nation adopts the policy of the nation with the highest performance currently in the system. In this way a nation which is doing poorly can see what nations which are doing well are doing, and try to follow that example.

This is the precedent-based characteristic of the model, which essentially assumes "copy-cat" behavior. If a nation is currently in Neutral, and sees diminishing performance, then it looks to see what other nations in the system are doing successfully. It adopts as policy the Mode of the nation with the best observed performance at the moment. In other words, short-term precedent-seeking allow the nation to have access to the results of the experimentation of all of the nations in the system.

This is a somewhat different precedent-searching mechanism that the models discussed earlier, since it relies on current behavior of other nations in the system rather than past behavior of the nation engaged in the policy. It is used for two reasons. First and most obviously, it does not require as much storage as a full historically-based precedent system. Second, it reduces the chance that the system will find an inappropriate precedent by confining the search to the recent past, when the system was in more or less the same configuration.

If the performance level is better than **Bad_Policy** but less than **OK_Policy**, and the a non-Neutral policy has been followed for more than one year, policy is shifted to Neutral. This is designed to fix the parameters at whatever they are at the moment.

If the performance is better than OK_Policy, then the nation continues with whatever policy it was following. Thus for example, if it was decolonizing, it will drop another colony, if it was bellicist, it will start another war and so forth.

2.3.1. Experimentation

The other cause of policy change is experimentation -- the random selection of a policy when one is in the Neutral mode. This is done with a fixed probability whenever the nation is in the Neutral mode and, in the experiments I have done, accounts for a lot of the change in the system.

Experimentation has two roles. From a modeling standpoint, it is a realistic addition to the model which reflects stochastic shifts in governmental decision-making. For example, a nation may decide to decolonize because of an assortment of reasons that are not directly related to the success or failure of that colonial policy. The use of random experimentation serves as a surrogate for vastly more complex internal changes in government and public opinion which cause policies to change even when the external environment has not significantly changed. From the standpoint of the running of the simulation, the experimentation provides the input which allows the system to show diverse behavior and to learn. The rule that mediocre performance moves a nation to a Neutral policy should keep the behavior bounded, but adding in addition stochastic experimentation should allow it to learn.

2.3.2. Limited Rationality

A very important thing to keep in mind about this system is that it employs limited rationality. It is a dumb system, and it is very deliberately dumb: it has been designed to be dumb and slow because foreign policy bureaucracies are, arguably, dumb and slow. As it turns out, it is because of this that the simulation models plausible behaviors fairly well. It is, in fact, sometimes a frustrating system to watch, since, for example, a weak colonial power will be sitting around for a while waiting to be picked off, and the system will be agonizingly slow in getting around to it. This is a very different type of behavior than most simulations that I am aware of, which usually operate much more quickly and are far more likely to exhibit optimal behavior. All-machine simulations do this through mathematical optimization techniques which are often extremely clever and information-intensive techniques; human decision-makers in human-machine simulations often shift policies more quickly and with fewer constraints than real-world bureaucracies.

3. RESULTS

3.1. Parameter Settings

The system was tested with the parameter values set as shown in the Appendix. The basic system studied was initialized with twenty independent nations of three general types

Large		
	Approx GNP	120
	Milex	6%
	ΔGDP	2%
Medium		
	GNP	40
	Milex	3%
	ΔGDP	2%
Small		
	GNP	10
	Milex	2%
	ΔGDP	4%

The system contains five large, five medium and ten small nations. Colonial and trade linkages were initially set at zero.

The values of the remaining parameters are given in the Appendix. These provide for a simulated world where large powers benefit primarily from imperialism and trade. War is a fairly costly proposition, costing all of yearly military expenditure when fought between equals. Colonial exploitation is ruthless and extracts a sizeable percentage (10%) of the GNP of the colonized nation, so the colony suffers limited growth as a consequence. The comparative advantage of trade gives 2% advantage to trading over internal growth, so there is a positive incentive to trade. Large and medium powers have relatively slow economic growth, and the large powers spend a great deal on the military. The small nations have much higher growth but start out with only a fraction of the wealth of the large powers.

As with all simulations, these parameter values are, of course, somewhat arbitrary, and in the little experimenting I did, the system does not appear highly sensitive to the parameters, though some changes occur. In terms of timing, the relation of simulation time to "real" time is probably something like three or four to one: in other words, in five simulation years, one sees a level of activity which might be appropriate for twenty years.

3.2. Overall Behavior

The simulation was run a large number of times and the behavior observed. Two of these runs are summarized at the end of the paper in a script which reports the actions taken in each year, and a statistical summary which shows the state of the system at five year intervals. One run, labeled the Trade Exhibit, has a great deal of trade activity and is somewhat atypical: this run shows some interesting colonial activity as well. The other run, labeled the Imperialism Exhibit, is more typical of the behavior except for the relative absence of war in the latter half of the run.

The first and most fundamental observation about the behavior of the system is that it works: the exhibited behaviors are stable (in the sense that the system is self-correcting), there is quite a variety of plausible activity and interaction, and the system does not immediately degenerate into a predictable pattern based on the initial conditions(e.g. a single powerful nation). This, in turn, is a problem for describing the system: it can in fact exhibit a number of different behaviors. The comments in this section will therefore try to give a general indication of how the system seems to be operating in addition to dealing with the two runs which are presented.

One of the most interesting characteristics of the system is the variety of different types of behavior individual nations can exhibit. While, as one would expect, large nations tend to remain large and small nations tend to get colonized, counter-examples occur. Frequently one or more of the minor nations will end up larger than the middle or major nations, and in one run a minor nation managed to grow sufficiently large to colonize a major nation that had been on the losing end of several wars. In all cases a great deal of shuffling in size occurs between the beginning and end of the simulation, and one can see the rise and fall of empires and trading systems in some runs.

3.1. Experimentation .vs. Precedent-Seeking

As is apparent from the text listings, the most frequent factor in changing behavior is experimentation rather than precedent seeking, though precedent-seeking is used on some occasions. However, the sheer frequency is somewhat deceptive for a couple of reasons. First, quite a bit of inappropriate experimentation is done, such as the use of the DeCol strategy by nations without colonies, the Autarky strategy by nations not engaged in trade, and the Imper strategy by nations too small to find anyone to colonize. These innovations are unsuccessful and the nation reverts to Neutral status. Obviously a couple of lines of code could eliminate such experiments.

Overall the precedent-seeking which does occur seems to have more impact on the system than the random experimentation. The two policies which diffuse are the Imper

and Liberal strategies, and when the system is particularly ripe for imperialism (such as when several minor nations have obtained sufficient wealth that they are attractive targets and via their experimentation with the Pac strategy have reduced their Milex), it will diffuse through the system and there will be a fairly quick (ten year) transition from a state of one or two colonies to ten or more.

As the scripts make clear, one of the most frequent policies adopted is Neutral. There is a simple, and not wholly credible, reason for this. The most frequent cause for an increase in performance -- which is the ratio of observed to expected GNP -- is through gaining a trading partner, which can only be done if one is in the Neutral or Liberal mode Ergo, even though the reason for the good performance is trade -- which would imply adopting a Liberal policy -- the actual policy which led to that trade may be Neutral. I haven't decided whether this should be considered a bug or a feature.

The limits for setting policy -- Bad_Policy and OK_Policy -- were probably set too wide to evoke a lot of precedent- seeking -- the performance measures are almost always within a couple percentage points of 1.0 and the policy change points were set at about five points outside 1.0. Narrowing the range of these parameters would increase the use of precedent-seeking and policy reversal.

3.3. Imperialism

With the settings of the system parameters used in the simulation runs, the system almost invariably ends up with some colonialism, though these can take a variety of forms. The typical run ends up with three or four nations acquiring colonies. The colonial systems established at the end of the simulation usually were accumulated through a combination of direct imperialism and winning wars against other colonial powers, a feature having much in common with the European system.

Because possession of colonies attracts attackers, it is difficult for a middle power to hold onto colonies. In the typical run, middle powers acquire colonies early on, but those colonies are then taken by a larger nation. Exceptions to this occur when the middle power has also acquired sufficient trade links to build up adequate GNP to resist attacks by larger powers, or is just plain lucky and is not successfully attacked.

Because the level of exploitation of the colony by the imperial power is set fairly high (10% of GNP per year), a nation which is colonized early in the simulation will experienced a declining GNP the remainder of the time. The situation of Fallia in the Imperialism Exhibit (where imperialism occurs fairly late in the simulation), or of Asgard, Damogran, Sol III and Al Centu in the Trade Exhibit are typical of this pattern. This means that in the long run, the colonies are of little use to the imperial power, and in fact probably only

serve to attract attackers. Thus, for example, Al Centu manages to go through four owners (Jaglan B, Altair, Sirius and Dentrass) in twenty years while its GNP of around 5.0 contributes virtually nothing to its owners. As such, Al Centu acts as the Lebanon of PWORLD.

The acquisition of Al Centu by Jaglan B illustrates one other fairly common phenomenon, which is small powers picking up colonies discarded by larger powers. Al Centu was originally colonized by Dentrass, its GNP was driven to low levels, then dropped by Dentrass and briefly picked up as a colony by Jaglan B. This type of exchange occurs fairly often late in the simulation. Because colonizers have to be substantially larger than colonies (4 times in this case), about the only way a small power can be imperialist is to take over a colony previously bankrupted by another colonizer.

Decolonization occurs entirely by experiment and seems to be a fairly innocuous to positive strategy. Since colonization usually reduces the GNP of colonies to a fairly worthless level anyway (unless those colonies have strong trade links), discarding them results in little economic loss and reduces both Milex and the possibility that one will be the target of a bellicist nation. Since decolonization is a strategy which is only meaningful for nations which have colonies in the first place, and at any given time usually only a small fraction of the nations in the system have colonies, decolonization is unlikely to diffuse as a strategy in the system, but does provide some additional flexibility in the behavior pattern exhibited.

3.4. Trade

The Trade Exhibit shows a system which is dominated by trade links, though it also has some imperialism. Because trade is done with nations closest in size, one frequently finds some sets of 2 to 4 nations which are strongly engaged in mutual trade, exchanging multiple chunks of trade with the same partner. Thus, in the Trade Exhibit, Algol, Fallia and Jaglan B are engaging in mutual trade, as are Arcturus and Dentrass, and Viltvodl and Eadrax.

Trade is clearly the "power strategy" in this simulation, since it increases the rate of growth. The strong interlinkage between Viltvodl and Eadrax illustrates this -- the two nations far surpass the others in growth due to their maximal (20%) trade linkages. This strategy also is pursued by the smaller nations -- for example it is not uncommon to see strong linkages between Sol III, Bethsela and Al Centu (when they avoid being colonized) since they are at the bottom of the list in wealth. Once those linkages are established, those nations grow together and at times become quite large.

In some early experiments, I raised the Trade_Mult parameter to 4% and this resulted in much stronger tendencies to establish trade links that the example given here. At the

4% trade level, many nations quickly established strong trading relationships, up to the maximum amount Max_Trade. In fact, one fairly common pattern is the establishment of a system which is primarily driven by trade with relatively little conflict. This is more likely to occur when a number of nations experiment with the Pacifist strategy early in the simulation: this has the effect of increasing growth to give good performance, and decreases the military strength so that if a major nation does experiment with imperialism or war, it draws or loses. Ironically, a loss in a non-imperialist war may augment a trading strategy, as it halves Milex. Since trading nations have, in the long run, high amounts of growth, they eventually become too large to be successfully attacked.

3.4. War

As noted earlier, the system was designed to make war a risky proposition, and as a consequence one did not, for the most part, find nations engaging in a lot of war. As the summaries indicate, the median number of wars is around 3, and since each war is counted twice (once for the initiator and once for the defender), this means a median of 1.5 wars initiated.

The primary function of war seems to be as a disincentive of colonialism, particularly by smaller powers. Since a bellicist nation decides who to attack based on which nation smaller than it has the largest number of colonies, a middle power acquiring colonies becomes a lightening rod for attacks by larger nations. The typical situation for a middle power acquiring colonies early in the simulation is to lose them in a war. A counter-example is found in the Imperialism Exhibit, where the middle power Eadrax acquires colonies and then since no major powers subsequently experiment with the Bellicist mode, it keeps those colonies. The more typical pattern is the acquisition and then loss through war of colonies by Altair, Jaglan B and Sirius in the Trade Exhibit.

Since a successful war results in a transfer of GNP from the defeated to the victor, it results in a temporary increase in the Perform index and hence is a policy likely to be imitated. However, because wars only result in an increase when won, and draws (which cost) are quite likely against nations roughly the same size, war (unlike imperialism) does not work well as a general strategy.

An example of the effects of high war involvement is Altair in the Trade Exhibit which experienced an unusually high total of 17 wars in the fifty-year period. Altair acquires two colonies early (by year 15), which subsequently makes it a prime target for attacks. Thus Altair is attacked by Megratha, which is only slightly larger than Altair in size, in years 23, 24, 27, and 28 but Megratha draws each time (meanwhile Megratha, initially a major power, has become comparable in size to Altair through the lack of any

trade and all these wars...). Altair continues to survive attacks, fends off a revolt by Damogran, attacks and defeats the slightly smaller Jaglan B on the second try at a war, acquiring a third colony in the process and finally succumbs in a war with Sirius, by now almost ten times larger. The upshot of all of this activity, however, leaves Altair, originally a middle power, at about half the GNP level of the uncolonized minor powers.

The opposite strategy of war: Pacifism (reduction of Milex) is used a lot experimentally and can be used quite successfully. So, for example, the largest nation in the Trade Exhibit by year 50 is Viltvodl, which had reduced Milex to the minimal 0.01 level by year 10, and in the Imperialism Exhibit Viltvodl (name is coincidental) has the second largest GNP with a Milex of 0.018. The strategy used by both Viltvodl's is to combine high trade and low Milex so that the sheer size of the GNP produces a total military expenditure large enough to deter attacks.

4. Discussion and Conclusion

The discussion above gives a general flavor for the type of behavior exhibited in the simulation. In general, the patterns generated are highly varied but at the same time plausible, and the behavior of the system remains bounded.

So, what good is this? While I would hardly expect this to replace GLOBUS or SARUM(it also cost somewhat less...), it might have some utility. First, it shows that a system primarily driven by qualitative policy change can exhibit plausible and bounded international behavior. Given the increasing interest in qualitative and rule-based models, and more generally a movement in the formal modeling community away from simplistic attempts to fit international relations into the Procrustean bed of classical mathematics, this type of effort might find some use. Second, to the extent that the precedent-based policy making as opposed to experimentation was utilized the model indicates that this can be incorporated as a dynamic mechanism. In particular, it is my opinion that the bounded rationality incorporated into this model provides more plausible and interesting patterns than the mathematically optimizing routines found in some earlier work.

Finally, the model is perhaps useful as a scenario generator showing how a system might evolve from a given set of initial conditions based on random policy experimentation. More generally what the model provides through multiple simulation runs is an envelope of possibilities of system evolution from a given initial value and set of parameters rather than making a single point prediction. In other words while the model produces a variety of behaviors it does not produce infinitely varied behaviors. For

example, some imperialism is found in virtually all of the runs, but unlike some optimizing simulations which incorporate imperialism, one never gets the "Roman empire" scenario, where a single nation comes to dominate the entire system. Thus under the initial conditions I've worked with, limited imperialism is inside the envelope of possibilities; total imperialism is outside of it.

This envelope of possibilities approach in turn relates somewhat to issues in the mathematical theory of chaos, which can be used to describe systems whose general behavior is predictable but whose specific, micro-level behavior is not. Thus, for example, one can predict the general characteristics of the turbulent flow of smoke rising from a cigarette -- the smoke will generally rise, it will contain whorls which have generally predictable shapes and movements and the smoke will generally respond in predictable ways to disturbances such as a light breeze -- but the exact path of any given particle in the stream of smoke is effectively unpredictable because of the chaotic nature of the equations describing its dynamics. These envelopes are essentially the same as the set predictions which, as I've argued extensively elsewhere (Schrodt 1986a,1986b), are probably more useful than point prediction in modeling international events.

The model as it stands is probably a bit too dumb, and could use a little more intelligence and a little slowing down to be more finely tuned. Clearly the level of experimentation is too high, though it was set high in part to see whether a highly random environment would crash the system, which it did not. This would involve a simple parameter change. Second, the memory of the system is very short -- the time horizon I used was only two or three years (depending on how you count). The ideal system would bias a nation towards first looking for past precedents in its own history -- and looking over all of that history -- rather than simply scanning the current system. That, in turn, would probably mean that there was more adoption of strategies other than the Neutral strategy, since a nation could find non-Neutral strategies in its past even if those were the only examples available in the present. This could be done with a bit of a programming and a lot of investment of additional memory. Finally, a few more rules might make the system behave a bit more credibly: for example, a lot of experimentation is currently inappropriate for the nations involved (e.g. decolonization for nations with no colonies)

TRADE EXHIBIT -- Summary -- Page 1

Year 0

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars
Vogon	140.00	0.068	NEU	1.00	0	0	0
Sirius	130.00	0.065	NEU	1.00	0	0	0
Megratha	120.00	0.063	NEU	1.00	0	0	0
Arcturus	110.00	0.060	NEU	1.00	0	0	0
Dentrass	100.00	0.058	NEU	1.00	0	0	0
Viltvodl	50.00	0.028	NEU	1.00	0	0	0
Eadrax	45.00	0.026	NEU	1.00	0	0	0
Altair	40.00	0.024	NEU	1.00	0	0	0
UM-Beta	35.00	0.022	NEU	1.00	0	0	0
Asgard	30.00	0.020	NEU	1.00	0	0	0
Algol	14.00	0.029	NEU	1.00	0	0	0
Santragi	13.00	0.028	NEU	1.00	0	0	0
Fallia	12.00	0.027	NEU	1.00	0	0	0
Jaglan B	11.00	0.026	NEU	1.00	0	0	0
Fakrafoo	10.00	0.025	NEU	1.00	0	0	0
Traal	9.00	0.024	NEU	1.00	0	0	0
Damogran	8.00	0.023	NEU	1.00	0	0	0
Sol III	7.00	0.022	NEU	1.00	0	0	0
Bethsela	6.00	0.021	NEU	1.00	0	0	0
Al Centu	5.00	0.020	NEU	1.00	0	0	0

Year 5

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars
Vogon	156.08	0.068	LIB	1.00	0	1	0
Sirius	137.57	0.065	BEL	1.00	0	1	1
Megratha	125.53	0.053	PAC	1.00	0	0	1
Arcturus	140.67	0.060	NEU	1.00	0	2	0
Dentrass	129.73	0.058	NEU	1.00	0	2	0
Viltvodl	57.80	0.018	NEU	1.00	0	0	0
Eadrax	51.97	0.026	NEU	1.00	0	0	0
Altair	46.21	0.024	NEU	1.00	0	0	0
UM-Beta	40.44	0.022	NEU	1.00	0	0	0
Asgard	33.74	0.020	NEU	1.00	0	0	2
Algol	16.29	0.019	NEU	1.00	0	0	2
Santragi	15.73	0.028	NEU	1.00	0	0	0
Fallia	14.52	0.027	NEU	1.00	0	0	0
Jaglan B	13.32	0.026	NEU	1.00	0	0	0
Fakrafoo	12.11	0.025	NEU	1.00	0	0	0
Traal	10.90	0.024	NEU	1.00	0	0	0
Damogran	9.69	0.023	NEU	1.00	0	0	0
Sol III	8.48	0.022	NEU	1.00	0	0	0
Bethsela	7.27	0.021	NEU	1.00	0	0	0
Al Centu	6.06	0.020	NEU	1.00	0	0	0

Year 10

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars
Vogon	201.31	0.068	NEU	1.00	0	2	0
Sirius	157.66	0.065	NEU	1.00	0	1	2
Megratha	133.49	0.053	NEU	1.02	0	0	4
Arcturus	199.54	0.060	NEU	1.00	0	3	0
Dentrass	171.41	0.058	NEU	1.00	0	2	0
Viltvodl	68.06	0.009	NEU	0.95	0	1	2
Eadrax	68.13	0.026	NEU	0.98	0	1	0
Altair	56.54	0.024	NEU	0.98	0	0	0
UM-Beta	46.80	0.012	NEU	1.00	0	0	0
Asgard	39.00	0.020	NEU	1.00	0	0	2
Algol	19.75	0.019	NEU	1.00	0	0	2
Santragi	19.04	0.028	NEU	1.00	0	0	0
Fallia	17.58	0.022	PAC	1.00	0	0	0
Jaglan B	16.12	0.026	NEU	1.00	0	0	0
Fakrafoo	17.11	0.015	PAC	1.00	0	2	0
Traal	15.64	0.024	NEU	1.00	0	2	0
Damogran	11.93	0.023	NEU	1.00	0	1	0
Sol III	10.47	0.022	LIB	1.00	0	1	0
Bethsela	8.81	0.021	NEU	1.00	0	0	0
Al Centu	7.34	0.020	NEU	1.00	0	0	0

Year 15

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	268.26	0.068	NEU	1.02	0	3	0	
Sirius	200.44	0.065	NEU	1.04	0	2	2	
Megratha	146.63	0.053	NEU	1.00	0	0	4	
Arcturus	280.70	0.060	NEU	1.00	0	3	0	
Dentrass	246.48	0.058	NEU	1.05	0	4	0	
Viltvodl	95.15	0.009	NEU	1.06	0	3	2	
Eadrax	95.03	0.026	NEU	1.06	0	3	0	
Altair	75.77	0.034	NEU	1.00	2	0	2	
UM-Beta	54.20	0.007	NEU	1.00	0	0	0	
Asgard	45.08	0.020	NEU	1.00	0	0	2	
Algol	23.95	0.014	PAC	1.00	0	0	2	
Santragi	23.04	0.028	NEU	1.00	0	0	0	
Fallia	21.32	0.017	NEU	1.00	0	0	0	
Jaglan B	19.52	0.026	NEU	1.00	0	0	0	
Fakrafoo	24.67	0.015	NEU	1.00	0	2	0	
Traal	22.85	0.024	NEU	1.00	0	2	0	
Damogran	9.56	0.011	NEU	0.98	0	1	1	Altair
Sol III	9.16	0.011	NEU	0.96	0	1	1	Altair
Bethsela	11.67	0.021	NEU	1.06	0	2	0	
Al Centu	8.90	0.020	NEU	1.00	0	0	0	

Year 20

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	376.22	0.068	NEU	1.00	0	3	0	
Sirius	264.26	0.065	NEU	1.00	0	2	2	
Megratha	161.06	0.053	NEU	1.00	0	0	4	
Arcturus	399.34	0.060	NEU	1.00	0	3	0	
Dentrass	384.74	0.058	BEL	1.00	1	4	1	
Viltvodl	145.87	0.009	NEU	1.00	0	3	2	
Eadrax	145.43	0.026	NEU	1.00	0	3	0	
Altair	96.42	0.034	NEU	1.00	2	0	2	
UM-Beta	62.76	0.007	NEU	1.00	0	0	0	
Asgard	51.45	0.012	NEU	1.04	0	0	4	
Algol	28.55	0.014	BEL	1.00	0	0	4	
Santragi	27.88	0.028	NEU	1.00	0	0	0	
Fallia	25.19	0.017	NEU	1.00	0	0	2	
Jaglan B	23.62	0.026	NEU	1.00	0	0	0	
Fakrafoo	35.66	0.015	NEU	1.00	0	2	0	
Traal	33.40	0.024	NEU	1.00	0	2	0	
Damogran	7.67	0.011	NEU	1.00	0	1	1	Altair
Sol III	7.35	0.011	NEU	1.00	0	1	1	Altair
Bethsela	15.94	0.021	NEU	1.00	0	2	0	
Al Centu	7.47	0.010	NEU	0.77	0	0	1	Dentrass

Year 25

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	527.39	0.068	NEU	1.00	0	3	0	
Sirius	369.90	0.065	NEU	1.04	0	4	2	
Megratha	169.35	0.053	NEU	0.96	0	0	6	
Arcturus	574.70	0.060	NEU	1.00	0	3	0	
Dentrass	590.04	0.058	NEU	1.00	1	4	2	
Viltvodl	265.53	0.009	NEU	1.11	0	7	2	
Eadrax	243.48	0.026	NEU	1.06	0	5	0	
Altair	114.68	0.034	NEU	0.97	2	0	5	
UM-Beta	72.18	0.007	NEU	1.00	0	0	1	
Asgard	59.53	0.012	NEU	1.00	0	0	4	
Algol	37.98	0.014	BEL	1.02	0	2	7	
Santragi	38.47	0.028	NEU	1.04	0	2	0	
Fallia	31.12	0.017	NEU	1.00	0	1	2	
Jaglan B	31.13	0.026	LIB	1.04	0	3	0	
Fakrafoo	51.21	0.010	NEU	0.99	0	2	1	
Traal	48.82	0.024	NEU	1.00	0	2	0	
Damogran	5.77	0.011	NEU	0.96	0	0	1	Altair
Sol III	5.89	0.011	NEU	1.00	0	1	1	Altair
Bethsela	21.97	0.021	NEU	1.04	0	3	1	
Al Centu	5.39	0.010	NEU	1.00	0	0	1	Dentrass

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Year 30

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	741.55	0.068	NEU	1.00	0	3	0	
Sirius	571.52	0.065	NEU	1.00	0	4	2	
Megratha	177.39	0.053	NEU	0.98	0	0	8	
Arcturus	827.56	0.060	NEU	1.00	0	3	0	
Dentrass	900.77	0.053	NEU	1.01	0	4	2	
Viltvodl	627.26	0.009	NEU	0.99	0	9	4	
Eadrax	550.58	0.031	NEU	1.00	1	7	1	
Altair	125.91	0.034	NEU	0.93	2	0	9	
UM-Beta	83.60	0.007	NEU	1.00	0	0	1	
Asgard	43.03	0.006	PAC	1.00	0	0	5	Eadrax
Algol	55.70	0.009	PAC	1.00	0	2	7	
Santragi	56.14	0.028	NEU	1.00	0	2	0	
Fallia	46.19	0.017	NEU	1.00	0	3	2	
Jaglan B	51.46	0.026	NEU	1.00	0	4	0	
Kalrafoo	74.43	0.010	NEU	1.00	0	2	1	
Traal	71.36	0.024	NEU	1.00	0	2	0	
Damogran	4.16	0.011	NEU	1.00	0	0	1	Altair
Sol III	4.73	0.011	NEU	1.00	0	1	1	Altair
Bethsela	33.37	0.021	LIB	1.00	0	4	1	
Al Centu	5.89	0.010	NEU	1.00	0	0	1	

Year 35

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	1262.60	0.068	NEU	1.02	0	6	0	
Sirius	868.61	0.065	NEU	0.98	0	3	2	
Megratha	194.85	0.053	NEU	1.00	0	0	8	
Arcturus	1282.09	0.060	NEU	1.01	0	4	0	
Dentrass	1376.57	0.053	NEU	1.01	0	4	2	
Viltvodl	1468.19	0.009	NEU	0.97	0	8	4	
Eadrax	1316.93	0.031	NEU	1.05	1	9	1	
Altair	149.42	0.034	NEU	1.00	2	0	10	
UM-Beta	96.81	0.007	NEU	1.00	0	0	1	
Asgard	29.53	0.006	NEU	1.00	0	0	5	Eadrax
Algol	81.67	0.009	NEU	1.00	0	2	7	
Santragi	81.93	0.028	NEU	1.00	0	2	0	
Fallia	77.47	0.017	NEU	1.00	0	4	2	
Jaglan B	86.40	0.031	NEU	1.02	1	4	2	
Kalrafoo	108.28	0.010	NEU	1.00	0	2	1	
Traal	104.30	0.024	NEU	1.00	0	2	0	
Damogran	3.00	0.006	NEU	1.00	0	0	2	Altair
Sol III	3.79	0.011	NEU	1.00	0	1	1	Altair
Bethsela	59.09	0.021	NEU	1.00	0	5	1	
Al Centu	5.51	0.002	NEU	0.86	0	0	3	Jaglan B

Year 40

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	2268.70	0.068	NEU	1.00	0	6	0	
Sirius	1252.27	0.065	NEU	1.00	0	3	2	
Megratha	202.78	0.053	NEU	0.97	0	0	10	
Arcturus	2022.96	0.060	NEU	1.00	0	4	0	
Dentrass	2113.77	0.053	NEU	1.01	0	4	2	
Viltvodl	3307.17	0.009	NEU	1.00	0	8	4	
Eadrax	3247.24	0.031	NEU	1.00	1	9	1	
Altair	169.29	0.034	BEL	0.98	3	0	15	
UM-Beta	109.65	0.012	NEU	0.99	0	0	5	
Asgard	20.26	0.006	NEU	1.00	0	0	5	Eadrax
Algol	118.76	0.009	NEU	1.00	0	2	8	
Santragi	116.58	0.028	NEU	0.98	0	2	2	
Fallia	121.00	0.017	NEU	1.00	0	4	2	
Jaglan B	134.11	0.015	NEU	1.00	0	4	4	
Kalrafoo	157.64	0.010	NEU	1.00	0	2	1	
Traal	152.44	0.024	NEU	1.00	0	2	0	
Damogran	2.16	0.006	NEU	1.00	0	0	2	Altair
Sol III	3.67	0.011	NEU	1.00	0	3	1	Altair
Bethsela	104.67	0.011	NEU	1.00	0	5	1	
Al Centu	6.11	0.002	NEU	1.00	0	3	1	Altair

Year 45

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	4136.83	0.058	PAC	1.03	0	7	0	
Sirius	1811.68	0.065	NEU	1.00	3	3	4	
Megratha	210.58	0.026	NEU	0.94	0	0	11	
Arcturus	3361.53	0.060	LIB	1.02	0	6	0	
Dentrass	3408.61	0.053	NEU	1.02	0	6	2	
Viltvodl	8326.47	0.009	NEU	1.02	0	10	4	
Eadrax	8191.49	0.031	NEU	1.00	1	10	1	
Altair	186.19	0.017	NEU	0.94	0	0	17	
UM-Beta	124.83	0.012	NEU	0.99	0	0	8	
Asgard	14.48	0.006	NEU	1.01	0	2	5	Eadrax
Algol	176.59	0.009	LIB	1.00	0	3	8	
Santragi	170.14	0.028	NEU	1.00	0	2	2	
Fallia	223.50	0.007	NEU	1.00	0	4	2	
Jaglan B	224.04	0.015	NEU	0.99	0	4	6	
Kalrafoo	229.66	0.010	NEU	1.00	0	2	1	
Traal	222.81	0.024	NEU	1.00	0	2	0	
Damogran	1.55	0.006	NEU	1.00	0	0	2	Sirius
Sol III	3.61	0.011	NEU	1.00	0	3	1	Sirius
Bethsela	188.49	0.011	NEU	1.00	0	6	1	
Al Centu	4.50	0.002	NEU	1.04	0	4	3	Sirius

Year 50

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	7719.73	0.068	NEU	1.01	2	6	2	
Sirius	2115.50	0.032	NEU	0.91	0	1	6	
Megratha	231.90	0.026	NEU	1.00	0	0	11	
Arcturus	6259.47	0.060	NEU	1.00	0	6	0	
Dentrass	5783.15	0.053	BEL	0.96	3	5	4	
Viltvodl	21026.3	0.009	NEU	1.00	0	10	4	
Eadrax	20434.8	0.031	NEU	1.00	1	10	1	
Altair	236.91	0.017	NEU	1.00	0	1	17	
UM-Beta	144.46	0.012	NEU	1.00	0	0	8	
Asgard	10.74	0.006	PAC	1.00	0	2	5	Eadrax
Algol	309.43	0.009	LIB	1.00	0	5	8	
Santragi	248.31	0.028	NEU	1.00	0	2	2	
Fallia	301.27	0.004	PAC	0.86	0	4	3	Vogon
Jaglan B	282.80	0.008	NEU	0.79	0	5	7	Vogon
Kalrafoo	334.76	0.010	NEU	1.00	0	2	1	
Traal	325.65	0.024	NEU	1.00	0	2	0	
Damogran	1.12	0.006	NEU	1.00	0	0	2	Dentrass
Sol III	3.56	0.006	NEU	1.00	0	3	1	Dentrass
Bethsela	361.46	0.011	NEU	1.00	0	6	1	
Al Centu	4.70	0.002	NEU	1.00	0	4	3	Dentrass

TRADE EXHIBIT -- Script -- Page 1

Year 1
Asgard experiments with IMP
Bell_Mode Asgard
War Asgard Algol
Viltvodl experiments with PAC
Pacif_Mode Viltvodl
Dentrass experiments with LIB
Lib_Mode Dentrass
Trade link to Arcturus

Year 2
Algol experiments with IMP
Imper_Mode Algol
Lib_Mode Dentrass
Trade link to Arcturus
Bell_Mode Asgard
War Asgard Algol
Pacif_Mode Viltvodl

Year 3
Al Centu experiments with DEC
Algol experiments with PAC
Pacif_Mode Algol

Year 4
Megratha experiments with DEC
Pacif_Mode Megratha
Pacif_Mode Algol
Damogran experiments with IMP
Imper_Mode Damogran

Year 5
Fallia experiments with BEL
Bell_Mode Fallia
Trade link to Sirius
Sirius experiments with LIB
Lib_Mode Sirius
War Sirius Damogran
Pacif_Mode Megratha
Eadrax experiments with AUT

Year 6
Eadrax experiments with DEC
Lib_Mode Eadrax
Trade link to Altair
Sol III experiments with AUT
Avoid experiments with LIB
Lib_Mode Vogon
Trade link to Altair
Bell_Mode Fallia
War Sirius Eadrax
Pacif_Mode Megratha

Year 7
Bell_Mode Megratha
War Megratha Viltvodl
Lib_Mode Traal
Trade link to Kalrafoo
Lib_Mode Eadrax
Trade link to Viltvodl
Pacif_Mode UM-Beta

Year 8
Bell_Mode Megratha
War Megratha Viltvodl
Victory

Year 9
Viltvodl experiments with DEC
Altair experiments with AUT
Autark_Mode Altair
Delink Eadrax
Kalrafoo experiments with PAC
Pacif_Mode Kalrafoo

Year 10
Fallia experiments with PAC
Pacif_Mode Fallia
Pacif_Mode Kalrafoo
Sol III experiments with LIB
Lib_Mode Sol III
Trade link to Damogran

Year 11
Dentrass experiments with DEC
Traal experiments with DEC
Lib_Mode Sol III
Trade link to Damogran
Pacif_Mode Fallia
Altair experiments with IMP
Imper_Mode Altair
War Altair Damogran
Victory
UM-Beta experiments with PAC
Pacif_Mode UM-Beta

Year 12
Damogran adopts Sol III policy NEU
Pacif_Mode UM-Beta
Imper_Mode Altair
War Altair Sol III
Victory

Year 13
Damogran adopts Altair policy NEU
Jaglan B experiments with IMP
Imper_Mode Jaglan B
Dentrass experiments with LIB
Lib_Mode Dentrass
Trade link to Sirius
Viltvodl experiments with LIB
Lib_Mode Viltvodl
Trade link to Eadrax
Autark_Mode Sol III
Delink Damogran
Bethsela experiments with LIB
Lib_Mode Bethsela
Trade link to Damogran

Year 14
Santragi experiments with DEC
Autark_Mode Sol III
Delink Damogran
Lib_Mode Viltvodl
Trade link to Eadrax
Lib_Mode Dentrass
Trade link to Vogon
Lib_Mode Bethsela
Trade link to Sol III

Year 15
Damogran experiments with IMP
Algol experiments with PAC
Pacif_Mode Algol
Kalrafoo experiments with IMP
Imper_Mode Kalrafoo

Year 16
Fallia experiments with BEL
Bell_Mode Fallia
War Fallia Algol
Pacif_Mode Algol
Altair experiments with AUT

Year 17
Megratha experiments with DEC
Bell_Mode Fallia
War Fallia Algol

Year 18
Asgard experiments with IMP
Imper_Mode Asgard
War Asgard Al Centu
Victory

Year 19
Al Centu adopts Asgard policy NEU
Imper_Mode Asgard

Year 20
Al Centu adopts Asgard policy NEU
Algol experiments with BEL
Bell_Mode Algol
Fallia experiments with AUT
Dentrass experiments with BEL
Bell_Mode Dentrass
War Dentrass Asgard
Victory

Year 21
Asgard experiments with DEC
Bell_Mode Algol
War Algol Bethsela
Traal experiments with DEC
Bell_Mode Dentrass
War Dentrass Altair

Year 22
Altair experiments with AUT
Santragi experiments with LIB
Lib_Mode Santragi
Trade link to Algol

Year 23
Lib_Mode Santragi
Trade link to Algol
Sirius experiments with LIB
Lib_Mode Sirius
Trade link to Viltvodl
Damogran experiments with AUT
Autark_Mode Damogran
Delink Bethsela
Kalrafoo experiments with PAC
Pacif_Mode Kalrafoo
Megratha experiments with BEL
Bell_Mode Megratha
War Megratha Altair
Viltvodl experiments with LIB
Lib_Mode Viltvodl
Trade link to Eadrax
Bethsela experiments with LIB
Lib_Mode Bethsela
Trade link to Jaglan B

Year 24
Damogran experiments with DEC
Bell_Mode Algol
War Algol Kalrafoo
Lib_Mode Bethsela
Trade link to Jaglan B
Al Centu experiments with DEC
Bell_Mode Megratha
War Megratha Altair
Lib_Mode Sirius
Trade link to Viltvodl
Pacif_Mode Kalrafoo
Lib_Mode Viltvodl
Trade link to Eadrax

Year 25
Vogon experiments with DEC
Bell_Mode Algol
War Algol UM-Beta
Jaglan B experiments with LIB
Lib_Mode Jaglan B
Trade link to Fallia

Year 26
Lib_Mode Jaglan B
Trade link to Fallia
Lib_Mode Viltvodl
Trade link to Eadrax

Year 27
Lib_Mode Viltvodl
Trade link to Eadrax
Megratha experiments with BEL
Bell_Mode Megratha
War Megratha Altair
Dentrass experiments with DEC
DeCol_Mode Dentrass
Delink Al Centu
Eadrax experiments with IMP
Imper_Mode Eadrax
War Eadrax Asgard
Victory

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Year  28
Asgard    adopts Al Centu policy NEU
Arcturus experiments with DEC
Altair    experiments with BEL
Bell_Mode Altair
  War Altair     Viltvodl
Bell_Mode Megratha
  War Megratha  Altair
Vogon     experiments with DEC

Year  29
Asgard    adopts Al Centu policy NEU
Bell_Mode Altair
  War Altair     Viltvodl
Algol     experiments with PAC
Pacif_Mode Algol

Year  30
Pacif_Mode Algol
Bethsela experiments with LIB
Lib_Mode Bethsela
    Trade link to Fallia
Asgard    experiments with PAC
Pacif_Mode Asgard

Year  31
Santragi experiments with DEC
Al Centu experiments with PAC
Pacif_Mode Al Centu
Lib_Mode Bethsela
    Trade link to Fallia
Vogon     experiments with LIB
Lib_Mode Vogon
    Trade link to Viltvodl
Pacif_Mode Asgard

Year  32
Pacif_Mode Al Centu
Lib_Mode Vogon
    Trade link to Arcturus

Year  33
UM-Beta   experiments with AUT
Eadrax    experiments with LIB
Lib_Mode Eadrax
    Trade link to Sirius
Viltvodl experiments with AUT
Autark_Mode Viltvodl
    Delink Sirius

Year  34
Damogran experiments with BEL
Bell_Mode Damogran
  Revolt Damogran
  War Altair     Damogran
    Victory
Jaglan B experiments with IMP
Imper_Mode Jaglan B
  War Jaglan B  Al Centu
    Victory
Autark_Mode Viltvodl
    Delink Sirius
Lib_Mode Eadrax
    Trade link to Vogon
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Year  35
Imper_Mode Jaglan B
Bell_Mode Al Centu
  Revolt Al Centu
  War Jaglan B  Al Centu
    Victory

Year  36
Al Centu adopts Eadrax    policy LIB
Lib_Mode Al Centu
    Trade link to Sol III
Altair    experiments with BEL
Bell_Mode Altair
  War Altair     Jaglan B
UM-Beta   experiments with BEL
Bell_Mode UM-Beta
Santragi experiments with DEC
Bethsela experiments with PAC
Pacif_Mode Bethsela

Year  37
Bell_Mode Altair
  War Altair     Jaglan B
    Victory
Megratha experiments with BEL
Bell_Mode Megratha
  War Megratha  Altair
Pacif_Mode Bethsela
Lib_Mode Al Centu
    Trade link to Sol III
Bell_Mode UM-Beta
  War UM-Beta    Algol

Year  38
Santragi experiments with BEL
Bell_Mode Santragi
  War Santragi  UM-Beta
Fallia    experiments with IMP
Imper_Mode Fallia
Bell_Mode Megratha
  War Megratha  Altair

Year  39
Bell_Mode Santragi
  War Santragi  UM-Beta
Kairafoo experiments with IMP
Imper_Mode Kairafoo

Year  40
Altair    experiments with BEL
Bell_Mode Altair
  War Altair     UM-Beta

Year  41
Fallia    experiments with PAC
Pacif_Mode Fallia
Bell_Mode Altair
  War Altair     UM-Beta
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Year  42
Viltvodl experiments with LIB
Lib_Mode Viltvodl
    Trade link to Eadrax
Damogran experiments with DEC
Asgard    experiments with LIB
Lib_Mode Asgard
    Trade link to Al Centu
Jaglan B experiments with BEL
Bell_Mode Jaglan B
  War Jaglan B  UM-Beta
Pacif_Mode Fallia

Year  43
Lib_Mode Viltvodl
    Trade link to Vogon
Lib_Mode Asgard
    Trade link to Al Centu
Sirius    experiments with BEL
Bell_Mode Sirius
  War Sirius     Altair
    Victory
Bell_Mode Jaglan B
  War Jaglan B  UM-Beta

Year  44
Arcturus experiments with LIB
Lib_Mode Arcturus
    Trade link to Dentrass
Bell_Mode Sirius
  War Sirius     Megratha
    Victory
Vogon     experiments with PAC
Pacif_Mode Vogon

Year  45
Altair    experiments with IMP
Imper_Mode Altair
Algol     experiments with LIB
Lib_Mode Algol
    Trade link to Bethsela
Pacif_Mode Vogon
Lib_Mode Arcturus
    Trade link to Dentrass

Year  46
Bethsela experiments with DEC
Lib_Mode Algol
    Trade link to Altair

Year  47
Viltvodl experiments with LIB
Sol III   experiments with PAC
Pacif_Mode Sol III

Year  48
Vogon     experiments with IMP
Imper_Mode Vogon
  War Vogon      Jaglan B
    Victory
Pacif_Mode Sol III
Sirius    experiments with AUT
Autark_Mode Sirius
    Delink Dentrass
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Year  49
Jaglan B adopts Vogon     policy N
Autark_Mode Sirius
    Delink Vogon
Dentrass experiments with BEL
Bell_Mode Dentrass
  War Dentrass  Sirius
Traal     experiments with IMP
Imper_Mode Traal
Imper_Mode Vogon
  War Vogon      Fallia
    Victory
Asgard    experiments with PAC
Pacif_Mode Asgard

Year  50
Sirius    adopts Vogon     policy N
Fallia    adopts Vogon     policy N
Jaglan B adopts Vogon     policy N
Pacif_Mode Asgard
Algol     experiments with LIB
Lib_Mode Algol
    Trade link to Jaglan B
Bell_Mode Dentrass
  War Dentrass  Sirius
    Victory
Fallia    experiments with PAC
Pacif_Mode Fallia
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Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	140.00	0.068	NEU	1.00	0	0	0	
Sirius	130.00	0.065	NEU	1.00	0	0	0	
Megratha	120.00	0.063	NEU	1.00	0	0	0	
Arcturus	110.00	0.060	NEU	1.00	0	0	0	
Dentrass	100.00	0.058	NEU	1.00	0	0	0	
Viltvodl	90.00	0.028	NEU	1.00	0	0	0	
Eadrax	45.00	0.026	NEU	1.00	0	0	0	
Altair	40.00	0.024	NEU	1.00	0	0	0	
UM-Beta	35.00	0.022	NEU	1.00	0	0	0	
Asgard	30.00	0.020	NEU	1.00	0	0	0	
Algol	14.00	0.029	NEU	1.00	0	0	0	
Santragi	13.00	0.028	NEU	1.00	0	0	0	
Fallia	12.00	0.027	NEU	1.00	0	0	0	
Jaglan B	11.00	0.026	NEU	1.00	0	0	0	
Kakrafoo	10.00	0.025	NEU	1.00	0	0	0	
Traal	9.00	0.024	NEU	1.00	0	0	0	
Damogran	8.00	0.023	NEU	1.00	0	0	0	
Sol III	7.00	0.022	NEU	1.00	0	0	0	
Bethsela	6.00	0.021	NEU	1.00	0	0	0	
Al Centu	5.00	0.020	NEU	1.00	0	0	0	

Year 5

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	153.55	0.068	NEU	1.00	0	0	0	
Sirius	142.62	0.065	NEU	1.00	0	0	0	
Megratha	131.68	0.063	NEU	1.00	0	0	0	
Arcturus	120.74	0.060	NEU	1.00	0	0	0	
Dentrass	109.79	0.058	NEU	1.00	0	0	0	
Viltvodl	60.78	0.028	NEU	1.02	0	2	0	
Eadrax	55.02	0.026	LIB	1.02	0	2	0	
Altair	46.21	0.024	NEU	1.00	0	0	0	
UM-Beta	40.44	0.022	NEU	1.00	0	0	0	
Asgard	34.68	0.020	NEU	1.00	0	0	0	
Algol	18.61	0.014	FAC	1.06	0	2	0	
Santragi	18.81	0.028	NEU	1.06	0	3	0	
Fallia	15.97	0.027	NEU	1.00	0	1	0	
Jaglan B	15.22	0.026	NEU	1.00	0	0	0	
Kakrafoo	12.11	0.025	NEU	1.00	0	0	0	
Traal	10.90	0.024	NEU	1.00	0	0	0	
Damogran	9.69	0.023	NEU	1.00	0	0	0	
Sol III	8.49	0.022	NEU	1.00	0	0	0	
Bethsela	7.27	0.021	NEU	1.00	0	0	0	
Al Centu	6.06	0.020	NEU	1.00	0	0	0	

Year 10

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	169.41	0.068	NEU	1.00	0	0	0	
Sirius	180.90	0.075	NEU	1.00	2	0	2	
Megratha	144.50	0.063	NEU	1.00	0	0	0	
Arcturus	132.52	0.060	NEU	1.00	0	0	0	
Dentrass	120.53	0.058	NEU	1.00	0	0	0	
Viltvodl	83.42	0.028	NEU	1.00	0	2	0	
Eadrax	76.79	0.026	NEU	1.00	0	2	0	
Altair	53.78	0.024	NEU	1.00	0	0	0	
UM-Beta	46.74	0.022	NEU	1.00	0	0	0	
Asgard	24.04	0.010	NEU	1.00	0	1	1	Sirius
Algol	26.46	0.009	AUT	1.00	0	1	0	
Santragi	19.61	0.014	NEU	0.98	0	2	1	Sirius
Fallia	20.45	0.027	NEU	0.98	0	0	0	
Jaglan B	16.12	0.026	NEU	1.00	0	0	0	
Kakrafoo	14.46	0.025	NEU	1.00	0	0	0	
Traal	12.42	0.024	NEU	1.00	0	1	0	
Damogran	11.96	0.023	LIB	1.00	0	1	0	
Sol III	10.27	0.022	NEU	1.00	0	0	0	
Bethsela	8.01	0.021	NEU	1.00	0	0	0	
Al Centu	7.35	0.010	NEU	1.00	0	0	0	

Year 15

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	165.03	0.063	PAC	0.95	0	0	2	
Sirius	194.32	0.075	NEU	0.94	2	0	4	
Megratha	161.30	0.063	NEU	1.00	0	1	0	
Arcturus	148.19	0.060	LIB	1.00	0	1	0	
Dentrass	132.33	0.058	NEU	1.00	0	0	0	
Viltvodl	114.88	0.018	NEU	1.00	0	2	0	
Eadrax	107.18	0.026	NEU	1.00	0	2	0	
Altair	61.67	0.024	NEU	1.00	0	0	0	
UM-Beta	54.01	0.022	NEU	1.00	0	0	0	
Asgard	18.08	0.010	NEU	1.00	0	1	1	Sirius
Algol	32.14	0.009	NEU	1.00	0	0	0	
Santragi	15.74	0.014	NEU	1.00	0	1	1	Sirius
Fallia	24.76	0.027	NEU	1.00	0	0	0	
Jaglan B	19.52	0.026	NEU	1.00	0	0	0	
Kakrafoo	17.75	0.025	NEU	1.00	0	0	0	
Traal	19.26	0.024	NEU	1.00	0	2	0	
Damogran	17.49	0.023	NEU	1.00	0	2	0	
Sol III	12.45	0.022	NEU	1.00	0	0	0	
Bethsela	10.68	0.021	NEU	1.00	0	0	0	
Al Centu	8.93	0.010	NEU	1.00	0	0	0	

Year 20

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	181.18	0.058	NEU	1.00	0	0	2	
Sirius	228.72	0.075	NEU	1.00	2	0	4	
Megratha	210.12	0.063	NEU	1.00	0	2	0	
Arcturus	195.83	0.050	FAC	1.00	0	2	0	
Dentrass	145.28	0.058	NEU	1.00	0	0	0	
Viltvodl	159.03	0.018	NEU	1.00	0	2	0	
Eadrax	162.89	0.026	NEU	1.06	2	2	2	
Altair	71.33	0.014	NEU	1.00	0	0	0	
UM-Beta	62.41	0.022	NEU	1.00	0	0	0	
Asgard	13.67	0.010	NEU	1.00	0	1	1	Sirius
Algol	38.58	0.009	NEU	0.99	0	0	2	
Santragi	12.64	0.014	NEU	1.00	0	1	1	Sirius
Fallia	20.75	0.013	NEU	0.77	0	0	1	Eadrax
Jaglan B	23.62	0.026	NEU	1.00	0	0	0	
Kakrafoo	20.79	0.025	NEU	0.97	0	0	2	
Traal	21.61	0.012	NEU	0.86	0	2	1	Eadrax
Damogran	25.50	0.023	NEU	1.00	0	2	0	
Sol III	15.08	0.022	NEU	1.00	0	0	0	
Bethsela	12.94	0.021	NEU	1.00	0	0	0	
Al Centu	10.84	0.010	NEU	1.00	0	0	0	

Year 25

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	198.91	0.058	NEU	1.00	0	0	2	
Sirius	262.99	0.075	NEU	1.00	2	0	4	
Megratha	269.95	0.063	NEU	1.00	0	1	0	
Arcturus	254.56	0.050	AUT	1.00	0	1	0	
Dentrass	159.50	0.058	NEU	1.00	0	0	0	
Viltvodl	222.55	0.018	NEU	1.00	0	2	0	
Eadrax	248.67	0.026	NEU	1.00	2	2	2	
Altair	82.53	0.014	NEU	1.00	0	0	0	
UM-Beta	72.12	0.022	NEU	1.00	0	0	0	
Asgard	11.05	0.010	LIB	1.02	0	2	1	Sirius
Algol	46.45	0.009	BEL	1.00	0	0	2	
Santragi	10.79	0.014	NEU	1.02	0	2	1	Sirius
Fallia	14.95	0.009	NEU	1.00	0	0	1	Eadrax
Jaglan B	28.62	0.016	FAC	1.00	0	0	0	
Kakrafoo	25.18	0.025	NEU	1.00	0	0	2	
Traal	19.25	0.012	NEU	1.00	0	2	1	Eadrax
Damogran	35.29	0.023	NEU	1.00	0	2	0	
Sol III	17.56	0.022	BEL	1.00	0	0	2	
Bethsela	15.40	0.021	NEU	1.00	0	0	1	
Al Centu	12.16	0.010	NEU	1.00	0	0	0	

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Year 30

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	218.38	0.058	NEU	1.00	0	0	2	
Sirius	299.30	0.075	NEU	1.00	2	0	4	
Megratha	296.23	0.063	NEU	1.00	0	0	0	
Arcturus	279.68	0.050	NEU	1.00	0	0	0	
Dentrass	175.11	0.058	NEU	1.00	0	0	0	
Viltvodl	311.45	0.018	NEU	1.00	0	2	0	
Eadrax	370.91	0.041	IMP	1.00	3	2	4	
Altair	95.48	0.014	NEU	1.00	0	0	0	
UM-Beta	71.13	0.011	NEU	1.00	0	0	1	Eadrax
Asgard	11.03	0.010	NEU	1.02	0	5	1	Sirius
Algol	55.95	0.009	NEU	1.00	0	0	4	
Santragi	11.29	0.014	LIB	1.02	0	5	1	Sirius
Fallia	10.76	0.004	PAC	1.00	0	0	2	Eadrax
Jaglan B	34.74	0.006	NEU	1.00	0	0	0	
Kakrafoo	30.49	0.025	NEU	1.00	0	0	2	
Traal	17.49	0.012	LIB	1.00	0	3	1	Eadrax
Damogran	46.68	0.023	NEU	1.00	0	2	0	
Sol III	20.45	0.022	NEU	1.00	0	0	4	
Bethsela	18.71	0.006	PAC	1.00	0	1	2	
Al Centu	15.98	0.010	NEU	1.00	0	0	0	

Year 35

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	239.75	0.058	NEU	1.00	0	0	2	
Sirius	329.52	0.065	NEU	1.00	0	0	4	
Megratha	325.22	0.053	NEU	1.00	0	0	0	
Arcturus	339.97	0.060	NEU	1.07	2	0	2	
Dentrass	192.25	0.058	NEU	1.00	0	0	0	
Viltvodl	435.86	0.018	NEU	1.00	0	2	0	
Eadrax	555.30	0.041	NEU	1.00	3	2	5	
Altair	110.46	0.014	NEU	1.00	0	0	0	
UM-Beta	52.02	0.011	NEU	1.00	0	0	1	Eadrax
Asgard	20.75	0.010	AUT	1.03	0	5	1	
Algol	52.63	0.005	NEU	0.76	0	0	6	Arcturus
Santragi	20.50	0.014	NEU	1.04	0	5	1	
Fallia	7.74	0.004	NEU	1.00	0	0	2	Eadrax
Jaglan B	42.22	0.006	NEU	1.00	0	0	0	
Kakrafoo	36.91	0.025	NEU	1.00	0	0	2	
Traal	19.02	0.012	NEU	1.00	0	4	1	Eadrax
Damogran	49.53	0.011	NEU	0.84	0	2	1	Arcturus
Sol III	24.77	0.022	NEU	1.00	0	0	4	
Bethsela	24.74	0.006	NEU	1.00	0	1	2	
Al Centu	21.34	0.010	NEU	1.00	0	1	0	

Year 40

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	263.22	0.058	NEU	1.00	0	0	2	
Sirius	361.50	0.065	NEU	1.00	0	0	4	
Megratha	357.22	0.053	NEU	1.00	0	0	0	
Arcturus	420.01	0.060	NEU	1.00	2	0	2	
Dentrass	240.31	0.068	NEU	1.04	2	0	2	
Viltvodl	609.96	0.018	NEU	1.00	0	2	0	
Eadrax	790.37	0.041	NEU	1.00	3	2	5	
Altair	129.88	0.014	NEU	1.00	0	0	2	
UM-Beta	35.76	0.011	NEU	1.00	0	0	1	Eadrax
Asgard	37.73	0.002	NEU	1.05	0	7	3	
Algol	37.87	0.005	NEU	1.00	0	0	6	Arcturus
Santragi	41.98	0.014	NEU	1.02	0	6	1	
Fallia	5.57	0.004	NEU	1.00	0	0	2	Eadrax
Jaglan B	32.03	0.003	PAC	1.00	0	0	1	Dentrass
Kakrafoo	31.06	0.012	NEU	0.77	0	0	3	Dentrass
Traal	18.00	0.012	NEU	0.96	0	2	1	Eadrax
Damogran	36.65	0.011	NEU	0.98	0	0	1	Arcturus
Sol III	31.19	0.022	NEU	1.02	0	1	4	
Bethsela	32.12	0.006	PAC	1.00	0	1	2	
Al Centu	31.07	0.010	NEU	1.04	0	3	0	

Year 45

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	288.98	0.058	NEU	1.00	0	0	2	
Sirius	396.59	0.065	NEU	1.00	0	0	4	
Megratha	392.38	0.053	NEU	1.00	0	0	0	
Arcturus	495.03	0.050	PAC	1.00	2	0	2	
Dentrass	292.26	0.068	NEU	1.00	2	0	2	
Viltvodl	853.61	0.018	NEU	1.00	0	2	0	
Eadrax	1097.20	0.041	NEU	1.00	3	2	5	
Altair	150.25	0.014	NEU	1.00	0	0	2	
UM-Beta	24.55	0.006	NEU	1.00	0	0	1	Eadrax
Asgard	73.99	0.002	NEU	1.00	0	6	3	
Algol	27.25	0.005	NEU	1.00	0	0	6	Arcturus
Santragi	75.32	0.009	PAC	1.01	0	4	1	
Fallia	4.01	0.004	NEU	1.00	0	0	2	Eadrax
Jaglan B	23.04	0.003	NEU	1.00	0	0	1	Dentrass
Kakrafoo	22.41	0.012	NEU	1.00	0	0	3	Dentrass
Traal	16.03	0.012	NEU	1.00	0	2	1	Eadrax
Damogran	26.43	0.011	NEU	1.00	0	0	1	Arcturus
Sol III	41.54	0.022	NEU	1.00	0	1	4	
Bethsela	40.87	0.006	NEU	1.00	0	1	2	
Al Centu	44.47	0.010	NEU	1.00	0	2	0	

Year 50

Name	GNP	Milex	Mode	Perf	#Col	#Trade	Wars	
Vogon	317.26	0.058	NEU	1.00	0	0	2	
Sirius	435.08	0.065	NEU	1.00	0	0	4	
Megratha	430.99	0.053	NEU	1.00	0	0	0	
Arcturus	585.65	0.055	IMP	1.00	3	0	3	
Dentrass	341.52	0.068	NEU	1.00	2	0	2	
Viltvodl	1409.81	0.018	NEU	1.00	0	4	0	
Eadrax	1752.69	0.041	NEU	1.01	3	4	5	
Altair	173.86	0.009	PAC	1.00	0	0	2	
UM-Beta	16.84	0.006	NEU	1.00	0	0	1	Eadrax
Asgard	118.53	0.001	NEU	1.00	0	6	4	Arcturus
Algol	19.61	0.005	NEU	1.00	0	0	6	Arcturus
Santragi	133.04	0.009	NEU	1.00	0	4	1	
Fallia	2.88	0.004	NEU	1.00	0	0	2	Eadrax
Jaglan B	18.36	0.003	NEU	1.06	0	2	1	Dentrass
Kakrafoo	17.96	0.012	NEU	1.07	0	2	3	Dentrass
Traal	12.32	0.012	NEU	0.96	0	0	1	Eadrax
Damogran	19.06	0.011	NEU	1.00	0	0	1	Arcturus
Sol III	55.34	0.022	NEU	1.00	0	1	4	
Bethsela	50.04	0.006	NEU	1.00	0	0	2	
Al Centu	60.21	0.010	NEU	0.99	0	1	0	

```
Year  1
Arcturus experiments with DEC
Fallia   experiments with LIB
Lib_Mode Fallia
    Trade link to Santragi
Algol    experiments with PAC
Pacif_Mode Algol
Damogran experiments with AUT
Sirius   experiments with DEC

Year  2
Kakrafoo experiments with DEC
Pacif_Mode Algol
Jaglan B experiments with IMP
Imper_Mode Jaglan B
Traal    experiments with DEC

Year  3
Santragi experiments with LIB
Lib_Mode Santragi
    Trade link to Algol
Jaglan B experiments with DEC
Megratha experiments with AUT

Year  4
Eadrax   experiments with LIB
Lib_Mode Eadrax
    Trade link to Viltvodl
Sol III  experiments with AUT
Lib_Mode Santragi
    Trade link to Algol

Year  5
Lib_Mode Eadrax
    Trade link to Viltvodl
Pacif_Mode Algol

Year  6
Pacif_Mode Algol
Sirius   experiments with IMP
Imper_Mode Sirius
  War Sirius     Asgard
     Victory

Year  7
Asgard   adopts Eadrax   policy LIB
Lib_Mode Asgard
    Trade link to Santragi
Imper_Mode Sirius
  War Sirius     Santragi
     Victory

Year  8
Asgard   adopts Sirius   policy NEU
Santragi adopts Sirius   policy NEU
Al Centu experiments with PAC
Pacif_Mode Al Centu
```



```
Year  9
Santragi adopts Asgard   policy NEU
Pacif_Mode Al Centu
Arcturus experiments with AUT
Santragi experiments with IMP
Fallia   experiments with AUT
Autark_Mode Fallia
    Delink Santragi

Year  10
Traal    experiments with IMP
Imper_Mode Traal
Algol    experiments with AUT
Autark_Mode Algol
    Delink Santragi
Damogran experiments with LIB
Lib_Mode Damogran
    Trade link to Traal

Year  11
Autark_Mode Algol
    Delink Santragi
Lib_Mode Damogran
    Trade link to Traal

Year  12
Santragi experiments with DEC
Sirius   experiments with BEL
Bell_Mode Sirius
  War Sirius     Vogon

Year  13
Bell_Mode Sirius
  War Sirius     Vogon
Viltvodl experiments with PAC
Pacif_Mode Viltvodl

Year  14
Vogon    adopts Viltvodl policy NEU
Sirius   adopts Viltvodl policy NEU
Pacif_Mode Viltvodl

Year  15
Al Centu experiments with IMP
Imper_Mode Al Centu
Arcturus experiments with LIB
Lib_Mode Arcturus
    Trade link to Megratha
Vogon    experiments with PAC
Pacif_Mode Vogon
Megratha experiments with DEC

Year  16
Altair   experiments with PAC
Pacif_Mode Altair
Pacif_Mode Vogon
Lib_Mode Arcturus
    Trade link to Megratha

Year  17
Pacif_Mode Altair
```

```
Year  18
Kakrafoo experiments with BEL
Bell_Mode Kakrafoo
  War Kakrafoo   Algol
Sol III  experiments with DEC
Eadrax   experiments with IMP
Imper_Mode Eadrax
  War Eadrax     Fallia
     Victory

Year  19
Fallia   adopts Eadrax   policy NEU
Arcturus experiments with PAC
Pacif_Mode Arcturus
Bell_Mode Kakrafoo
  War Kakrafoo   Algol
Imper_Mode Eadrax
  War Eadrax     Traal
     Victory

Year  20
Fallia   adopts Eadrax   policy NEU
Traal    adopts Eadrax   policy NEU
Pacif_Mode Arcturus

Year  21
Traal    adopts Eadrax   policy IMP
Sol III  experiments with AUT
Al Centu experiments with DEC

Year  22
Fallia   experiments with PAC
Pacif_Mode Fallia

Year  23
Traal    experiments with DEC
Pacif_Mode Fallia

Year  24
Sol III  experiments with AUT
Asgard   experiments with LIB
Lib_Mode Asgard
    Trade link to Santragi
Altair   experiments with DEC
Jaglan B experiments with PAC
Pacif_Mode Jaglan B

Year  25
Pacif_Mode Jaglan B
UM-Beta  experiments with DEC
Algol    experiments with BEL
Bell_Mode Algol
  War Algol      Sol III
Lib_Mode Asgard
    Trade link to Santragi
Sol III  experiments with BEL
Bell_Mode Sol III
  War Sol III    Bethsela
Arcturus experiments with AUT
Autark_Mode Arcturus
    Delink Megratha
```

```
Year  26
Fallia   experiments with BEL
Bell_Mode Fallia
  Revolt Fallia
  War Eadrax     Fallia
     Victory
Bell_Mode Algol
  War Algol      Sol III
Bell_Mode Sol III
  War Sol III    Bethsela
Vogon    experiments with AUT
Bethsela experiments with PAC
Pacif_Mode Bethsela
Autark_Mode Arcturus
    Delink Megratha

Year  27
Pacif_Mode Bethsela

Year  28
Jaglan B experiments with PAC
Pacif_Mode Jaglan B
Santragi experiments with IMP
Arcturus experiments with AUT

Year  29
Pacif_Mode Jaglan B
Santragi experiments with LIB
Lib_Mode Santragi
    Trade link to Asgard

Year  30
Eadrax   experiments with IMP
Imper_Mode Eadrax
  War Eadrax     UM-Beta
     Victory
Lib_Mode Santragi
    Trade link to Asgard
Traal    experiments with LIB
Lib_Mode Traal
    Trade link to Bethsela
Bethsela experiments with PAC
Pacif_Mode Bethsela
Fallia   experiments with PAC
Pacif_Mode Fallia

Year  31
UM-Beta  adopts Santragi policy IM
Sirius   experiments with DEC
DeCol_Mode Sirius
    Delink Asgard
Lib_Mode Traal
    Trade link to Al Centu
Al Centu experiments with DEC
Pacif_Mode Bethsela
Vogon    experiments with AUT
Imper_Mode Eadrax
  War Eadrax     Algol
Algol    experiments with LIB
Lib_Mode Algol
    Trade link to Damogran
Pacif_Mode Fallia
```

```
Year  32
UM-Beta  adopts Asgard   policy NEU
DeCol_Mode Sirius
    Delink Santragi
Lib_Mode Algol
    Trade link to UM-Beta

Year  33
Arcturus experiments with IMP
Imper_Mode Arcturus
  War Arcturus  Algol
     Victory
Megratha experiments with FAC
Paci_Mode Megratha
Lib_Mode Santragi
    Trade link to Asgard

Year  34
Paci_Mode Megratha
Imper_Mode Arcturus
  War Arcturus  Damogran
     Victory
Autari_Mode Algol
    Delink Damogran

Year  35
Damogran adopts Arcturus policy NEU
Asgard   experiments with AUT
Autark_Mode Asgard
    Delink Santragi
Autark_Mode Algol
    Delink UM-Beta

Year  36
Damogran adopts Arcturus policy IMP
Autark_Mode Asgard
    Delink Santragi
Altair   experiments with BEL
Bell_Mode Altair
  War Altair    Asgard
     Victory
Santragi experiments with LIB
Lib_Mode Santragi
    Trade link to Asgard

Year  37
Asgard   adopts Altair   policy NEU
Lib_Mode Santragi
    Trade link to Al Centu
Damogran experiments with AUT
Autark_Mode Damogran
    Delink Traal
Bell_Mode Altair
  War Altair    Asgard
     Victory
Dentrass experiments with IMP
Imper_Mode Dentrass
  War Dentrass  Jaglan B
     Victory

Year  38
Jaglan B adopts Dentrass policy NEU
Fallia   experiments with DEC
Imper_Mode Dentrass
  War Dentrass  Kakrafoo
     Victory
Lib_Mode Asgard
    Trade link to Al Centu
Algol    experiments with DEC
Autark_Mode Damogran
    Delink Traal

Year  39
Jaglan B adopts Dentrass policy NEU
Kakrafoo adopts Dentrass policy NEU
Jaglan B experiments with FAC
Paci_Mode Jaglan B
Kakrafoo experiments with IMP
Lib_Mode Asgard
    Trade link to Sol III

Year  40
Kakrafoo adopts Asgard   policy NEU
Paci_Mode Jaglan B
Viltvodl experiments with DEC
Bethsela experiments with FAC
Paci_Mode Bethsela

Year  41
Santragi experiments with AUT
Autari_Mode Santragi
    Delink Al Centu
Paci_Mode Bethsela

Year  42
Fallia   experiments with FAC
Paci_Mode Fallia
UM-Beta  experiments with FAC
Paci_Mode UM-Beta
Autark_Mode Santragi
    Delink Asgard

Year  43
Asgard   experiments with FAC
Paci_Mode Asgard
Paci_Mode UM-Beta
Paci_Mode Fallia
Altair   experiments with DEC

Year  44
Arcturus experiments with FAC
Paci_Mode Arcturus
Paci_Mode Asgard

Year  45
Paci_Mode Arcturus
Santragi experiments with FAC
Paci_Mode Santragi

Year  46
Eadrax   experiments with LIB
Lib_Mode Eadrax
    Trade link to Viltvodl
Paci_Mode Santragi

Year  47
Traal    experiments with AUT
Autark_Mode Traal
    Delink Bethsela
Algol    experiments with FAC
Paci_Mode Algol
Lib_Mode Eadrax
    Trade link to Viltvodl

Year  48
Asgard   experiments with IMP
Imper_Mode Asgard
Kakrafoo experiments with LIB
Lib_Mode Kakrafoo
    Trade link to Jaglan B
Autark_Mode Traal
    Delink Al Centu
Paci_Mode Algol

Year  49
Lib_Mode Kakrafoo
    Trade link to Jaglan B
Sol III  experiments with IMP
Imper_Mode Sol III

Year  50
Altair   experiments with FAC
Paci_Mode Altair
Arcturus experiments with IMP
Imper_Mode Arcturus
  War Arcturus  Asgard
     Victory
```

Appendix:
Key Elements of PWorld Program

This appendix gives condensed code for the simulation. I have left out an assortment of minor variable declarations, input/output, initializations and error traps but have left in most of the actual formulas. Angle brackets -- «...» -- denote the location of uninteresting large blocks of code which do standard actions (e.g. modify lists).

The complete code is available in either Apple II or Macintosh format from the author. The Pascal dialect is Apple II UCSD and should convert with little difficulty to Turbo Pascal. Program runs on a 64K Apple II with about 28K free with a system of 20 nations, so the system could obviously be expanded in size considerably.

```
Constants
    N_Nation = 20,              Number of nations in system
    Max_Colony = 10,            Max colonies nation can hold
    Max_Trade = 10,             Max trading chunks nation can have
    Max_Year = 50,              Length of simulation run

    Horizon = 2,                Time horizon for projections

    Trade_Mult = 1.02,    (* Comparative advantage gain of trade *)
    Trade_Chunk = 0.02,   (* Prop of GDP in a trade chunk *)

    War_Cost = 1.00,      (* Use to calculate cost of war *)
    War_Spoils = 0.05,    (* % GNP transfered from loser to winner *)
    Defeat_Milex= 0.50,   (* Milex reduction of loser *)
    D_Milex = 0.0050,   Incremental change in Milex in Bell_Mode,Pac_Mode
    Min_Milex = 0.01,     Minimum size for Milex

    Colony_Size = 0.25,   (* Max size of colony as % of colonizer GNP *)
    Colony_Cost = 0.0050, (* Colony cost as increment to Milex *)
    Tribute_Prop= 0.10,   (* Prop of GDP extracted by imperial power *)

    Bad_Policy = 0.92,     Trigger level for reversing policy
    OK_Policy = 1.05,      Trigger level for switching to Neutral policy
    Exper_Prob = 0.15,     Probability of experimenting with policy
```



```
Type ModeType = (Neut,Bell,Pacif,Lib,Aut,Imper,Decol);

  Natn = Record
      Name:                 String[8],
      GNP,
      Milex,                %GNP which are military expenditures
      DGDP,                 Yearly change in GDP
      Perform:              Real,
      Mode:                 ModeType,
      Owner,                Colonial owner; 0 if none
      N_Colony,N_Trade:     integer,
      Colony:               Array[1..Max_Colony] of integer,
      Trade:                Array[1..Max_Trade] of integer,
      Q_War:                records number of wars experienced
    end,

Var
 Nation:          Array[1..Max_Nation] of Natn,
 Q_Forecast:      Array[0..Horizon,1..Max_Nation] of real,
 M_Forecast:      Array[0..Horizon,1..Max_Nation] of ModeType,

Procedure Print_Stats;
(* Prints current statistics for nations *)

(* ***** ATTRIBUTE FUNCTIONS ***** *)

Function URan:real;
(* Uniform [0,1] random numbers *)

Function Opp_Mode(M:ModeType):ModeType;
(* Returns the opposite mode *)

Function GDP(na:integer):real;
(* Computes the non-military part of GNP *)

Function Q_Mil(NA:integer):real;
(* Computes quantity of military for NA *)

Function Q_Trade(na,nb:integer):real;
(* Computes the quantity of trade between na and nb *)
```

```
Function New_GNP(na integer):real;
(* Computes the new  GNP value *)
begin
 with Nation[na] do begin                    (* compute base GDP *)
    GD :=GDP(na);
    M := (Milex*GD)/(1.0-Milex);             (* Military component *)
    if Owner<>0 then GD :=(1.0 - Tribute_Prop)*GD;
    GD := DGDP  * GD + M;                    (* Intrinsic growth *)
                                             (* adjustments for colonies, trade *)
    if N_Colony >0 then
      for ka:=1 to N_Colony do GD := GD + Tribute_Prop*GDP(Colony[ka]);
    if N_Trade > 0 then
      for ka:=1 to N_Trade do GD := GD + Trade_Mult*Q_Trade[Trade[ka],na];

    New_GNP  := GD;
 end; (* with *)
end; (* New_GNP *)

Procedure Forecast;
(* Update the Forecast arrays *)

Procedure New_Perform;
(* Compute the performance measure *)

Function Exper_Mode:ModeType;
(* Randomly picks a new policy mode *)

              (* ***** WAR PROCEDURES ***** *)

Procedure War(na,nb integer);
(* War between NA and NB   Procedure assumes NA >= NB
  The War_Cost adjustment is algebraically equivalent to
    GNP := GNP - Q_Mil* (MilB/MilA) * War_Cost
  This procedure is used in both Bell_Mode and Imper_Mode *)
begin
 MilA :=Q_Mil[NA];
 MilB :=Q_Mil[NB];
                                  (* Subtract costs of war *)
 Nation[NA].GNP  := Nation[NA].GNP - MilB * War_Cost;
 Nation[NB].GNP  := Nation[NB].GNP - (Sqr(MilB)/MilA) * War_Cost;
```



```
 Nation[NA].Q_War  := Nation[NA].Q_War + 1;
 Nation[NB].Q_War  := Nation[NB].Q_War + 1;

 if URan < (MilA - MilB)/(MilA + MilB)       (* prob of victory for NA *)
 then begin
   with Nation[NB] do begin
    Milex  := Defeat_Milex * Milex;
    Mode   := Neut;
    if Owner<>NA then                  (* transfer spoils unless revolt *)
      begin
       Nation[NA].GNP  := Nation[NA].GNP + (GNP * War_Spoils);
       GNP  := GNP*(1.0 - War_Spoils);
      end;

    << Transfer colonies from NB to NA >>

    << Colonize NB if NA is in imperialist mode >>
  end; (* if URan*)
end; (* War *)

Procedure Bell_Mode(NA:integer);
(* Bellicist mode activity for NA *)
begin
   << if colonized, attack colonizer, then exit procedure >>

(* look for someone to attack based on
   1 Cannot be colony
   2 Must be weaker
   3 Maximize ratio of colonies to Q_Mil   *)
 Loc :=0;
 My_Mil  := Q_Mil[NA];
 for ka:=1 to N_Nation do
  if      (ka<>NA)
    and (Nation[ka].Owner=0)
    and (Q_Mil[ka] < My_Mil)
    and (((Nation[ka].N_Colony/Q_Mil[ka]) > Q_Target) or (Loc=0))
  then begin
         Q_Target := Nation[ka].N_Colony/Q_Mil[ka];
         Loc :=ka;
       end;
```

```
                                (* if target available, attack, else increment Milex *)
   if Loc > 0 then War(NA, Loc)
              else with Nation[NA] do Milex := Milex + D_Milex,
end, (* Bell_Mode *)

Procedure Pacif_Mode(NA integer),
(* Implement Pacif mode activities *)
begin
  with Nation[NA] do if Mi              _Milex then Milex := Milex - D_Milex,
end,

            (*  ***** IMPERIALISM PROCEDURES ***** *)

Procedure Imper_Mode(NA integer),
(* Implement Imper mode activities *)
begin
(* look for someone to colonize based on:
    1. Cannot be colony
    2. Must be substantially smaller
    3. Pick on wealthiest target  *)
 Best_Target:=0,
 My_GNP := Nation[NA].GNP,
 for ka:=1 to N_Nation do
  if      (ka<>NA)
    and (Nation[ka].Owner=0)
    and ((Nation[ka].GNP/My_GNP)  <= Colony_Size)
    and ((Nation[ka].GNP > Q_Target) or (Best_Target=0))
  then  begin
          Q_Target := Nation[ka].GNP,
          Best_Target :=ka,
        end,
                                (* if target available, attack, else Mode := Neut *)
   if Best_Target > 0 then War(NA, Best_Target)
              else Nation[NA].Mode := Neut,
end, (* Imper_Mode *)

Procedure DeCol_Mode(NA integer),
(* Implement DeCol activity: drop poorest colony *)
```



```
            (* **** TRADE PROCEDURES ***** *)

Procedure Lib_Mode(NA integer),
(* Implement Liberal activity: look for trading partner.  Note that one can have
multiple trade agreements with the same partner  *)
begin
<< If N_Trade=Max_Trade, change mode to Neutral, exit procedure >>
                (* Trade is established with the partner closest in wealth *)
 with Nation[NA] do begin
  My_GDP := GDP(NA),
  Loc:=0;
  for ka:=1 to N_Nation do
   if    (ka<>NA)
     and ((Nation[ka].Mode=Lib) or (Nation[ka].Mode=Neut))
     and (Nation[ka].N_Trade < Max_Trade)
     and ((Abs(My_GDP - GDP(ka)) < Best) or (Loc=0))
           then begin
                  Best := Abs(My_GDP - GDP(ka)),
                  Loc:=ka,
                end,
 end, (* with Nation[NA] *)

  if Loc>0 then  << Add to trading list of both nations >>
end, (* Liberal_Mode *)

Procedure Autark_Mode(NA integer),
(* Implement Autark activity: drop poorest trading partner in trading list,
   also delete oneself from that partners trading list *)

Procedure Pick_Policy(NA integer),
(* Main policy decision loop. M_Forecast[0,NA] is the policy that was being used
at t-Horizon, i.e. at the time the current performance projection was made *)
begin
 with Nation[NA] do begin
  if Perform < Bad_Policy then
   begin
    Mode := Opp_Mode(M_Forecast[0,NA]),
    if Mode = Neut then begin              (* Find best precedent *)
      Loc:=NA,
      Best:=Perform,
```

```
        for ka:=1 to N_Nation do
                        if Nation[ka].Perform > Best
                            then begin
                                    Best:=Nation[ka].Perform;
                                    Loc:=ka;
                                 end;
        Mode:=M_Forecast[0,Loc];
      end; (* then *)
     end (* then *)
  else if     (Perform  < OK_Policy)
        and (M_Forecast[1,NA]<>Neut)
     then Mode:=Neut;

  if Perform>OK_Policy then Mode:=M_Forecast[0,NA];
 end; (* with *)
end; (* Pick_Policy *)

Procedure Do_Policy;
(* Execute policies in random order *)
begin
 for ka:=1 to N_Nation do Done[ka]:=false;
 for ka:= 1 to N_Nation do begin
   kb:=Random mod N_Nation;
   Repeat
    kb:=kb+1;
    if kb>N_Nation then kb:=1;
   Until not Done[kb];
   Done[kb]:=true;
   if Nation[kb].Mode=Neut then
             if Uran < Exper_Prob then Nation[kb].Mode:=Exper_Mode;
   Case Nation[kb].Mode of
    Bell:Bell_Mode(kb);
    Pacif: Pacif_Mode(kb);
    Imper: Imper_Mode(kb);
    DeCol: DeCol_Mode(kb);
    Lib:   Lib_Mode(kb);
    Aut:   Autark_Mode(kb);
   end; (* case *)
  end; (* for *)
end; (* Do_Policy *)
```



```
(**** MAIN PROGRAM ****)
begin
 Init_Var;
 for year:=1 to Maxyear do begin
  New_Perform;
  for ka:=1 to N_Nation do Pick_Policy(ka);
  Do_Policy;
  for ka:=1 to N_Nation do Nation[ka].GNP := New_GNP(ka);
  Forecast;
  Print_Stats;
  end;
end.
```

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